



Calhoun: The NPS Institutional Archive
DSpace Repository

Theses and Dissertations

1. Thesis and Dissertation Collection, all items

1982

A statistical evaluation of military construction
project cost estimates.

Paine, William J.

Monterey, California. Naval Postgraduate School

<http://hdl.handle.net/10945/20350>

Downloaded from NPS Archive: Calhoun



<http://www.nps.edu/library>

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

A STATISTICAL EVALUATION OF MILITARY
CONSTRUCTION PROJECT COST ESTIMATES

by

William J. Paine

June 1982

Thesis Advisor:

D. C. Boger

Approved for public release; distribution unlimited

U205423

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Statistical Evaluation of Military Construction Project Cost Estimates		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; June 1982
7. AUTHOR(s) William J. Paine		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93940		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, CA 99340		10. PROGRAM ELEMENT, PROJECT TASK AREA & WORK UNIT NUMBERS
13. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE June 1982
		13. NUMBER OF PAGES 40
		14. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Congress, Naval Facilities Engineering Command, Military Construction Projects, Cost Estimates, Linear Regression Engineering Field Divisions		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The provision of accurate total construction cost estimates to the Congress is a continuing problem for the Naval Facilities Engineering Command. It is the purpose of this thesis to provide a series of equations which will reduce the variance of the actual total cost from the estimated total cost. When these equations are applied over the long run to all Military Construction projects, this variance could be reduced by approximately		

ninety percent.

These equations are derived through the use of statistical regression of the past eight years' Military Construction project's actual cost regressed on the project's authorized cost. A total of 1065 projects are compared and the resulting equations are assembled by Engineering Field Division (EFD) and by fiscal year.

In addition to the regression equations, an average project cost variation and a weighted cost variation is provided for each EFD. These variations can be used by the EFD's as trend indicators and measures of the overall effectiveness of the EFD's cost estimating practices.

Approved for public release: distribution unlimited

A Statistical Evaluation of Military Construction Project
Cost Estimates

by

William J. Paine

Lieutenant, United States Navy
B.B.C., University of Florida, 1975

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL

June 1982

ABSTRACT

The provision of accurate total construction cost estimates to the Congress is a continuing problem for the Naval Facilities Engineering Command. It is the purpose of this thesis to provide a series of equations which will reduce the variance of the actual total cost from the estimated total cost. When these equations are applied over the long run to all Military Construction projects, this variance could be reduced by approximately ninety percent.

These equations are derived through the use of statistical regression of the past eight years Military Construction project's actual cost regressed on the project's authorized cost. A total of 1065 projects are compared and the resulting equations are assembled by Engineering Field Division (EFD) and by fiscal year.

In addition to the regression equations, an average project cost variation and a weighted cost variation is provided for each EFD. These variations can be used by the EFD's as trend indicators and measures of the overall effectiveness of the EFD's cost estimating practices.

TABLE OF CONTENTS

I.	BACKGROUND	8
II.	MAJOR ASPECTS OF THE MILITARY CONSTRUCTION PROCESS	10
	A. THE CONGRESS	10
	B. NAVAL FACILITIES ENGINEERING COMMAND	14
	C. ENGINEERING FIELD DIVISIONS	14
	D. MAJOR CLAIMANT	15
	E. FACILITIES ACQUISITION AND CONSTRUCTION OFFICE	16
	F. COST ESTIMATES	16
	G. TIME ELEMENTS	18
	H. INFLATION	19
III.	ANALYSIS OF DATA	20
	A. INTRODUCTION	20
	B. DATA AND SOURCES	20
	C. METHODOLOGY	21
	D. RESULTS	23
	E. SUMMARY	28
IV.	CONCLUSIONS AND RECOMMENDATIONS	29
	A. CONCLUSION	29
	B. RECOMMENDATIONS	29
	APPENDIX A: EFD EQUATIONS	32
	APPENDIX B: MEANS AND AVERAGES	35
	APPENDIX C: SELECTED STUDENT'S T DISTRIBUTION VALUES . .	37
	LIST OF REFERENCES	38
	INITIAL DISTRIBUTION LIST	39

LIST OF TABLES

I.	Phase I	11
II.	Phase II	12
III.	Phase III	12
IV.	Phase IV	12
V.	Subcommittees of the Armed Services Committees, 95th Congress	13
VI.	Summary of Regression Equations	26

LIST OF FIGURES

2.1	General Chronology of Congressional Budget Action	11
2.2	United States Showing Locations of Engineering Field Divisions	15
3.1	Detailed Plot of Chesapeake Division Fitted Line and Prediction Interval	24
3.2	Plot of All Fitted Equations Including Bethesda and Trident West	27

I. BACKGROUND

The problem of making accurate construction cost estimates goes back to antiquity. There have been many cost estimating methods and concepts developed over the years. Most of these were used until they were superceded by a method or combination of methods which led to more accurate estimates of the actual cost of a project. There is still no one cost estimating method or combination of methods that will produce 100 percent accuracy 100 percent of the time.

This problem, which continues to plague the construction industry, is due to the industry's inability to project the total impact of all of the factors combined on construction costs at some point in the future. These factors include such variables as inflation, inconsistent but acceptable estimating practices, varying local conditions, i.e., labor rates and the cost of materials, as well as the changing political make up of the Congress in the case of military construction.

The purpose of this thesis is to provide adjustment factors to assist in the preparation of more accurate estimates of the actual total costs of Military Construction (MILCON) projects prior to their authorization by the Congress. A review of the past eight years' actual costs of all closed-out Navy MILCON projects, including Bethesda National Naval Medical Center and Trident West, will be used to derive the individual adjustment factors for each Engineering Field Division (EFD) and one for Naval Facilities Engineering Command (NAVFAC) as a whole. A method for updating these factors will also be provided.

Chapter I will discuss both the problems associated with accurate construction cost estimating and the approach to a solution as proposed by this thesis. Chapter II will be a discussion of the major influences that have an effect on MILCON cost estimates. These include a discussion of the Congressional role in the MILCON funding process and NAVFAC and the EFD and their roles in the MILCON cost estimating process. Chapter III will be a detailed discussion of the analysis of the data. Discussed are the data and their sources, the methodology used to obtain the factors, and the results of the data manipulation including a summary listing of the findings. Chapter IV will discuss the conclusions and recommendations reached as a result of the research. Appendix A will be a detailed listing of the findings segregated by EFD. Appendix B will be a detailed listing of additional information obtained during the research. This information will be useful in a comparison of the EFD's MILCON project programs. Appendix C will be a condensed table listing specific student's t distribution values available to be used in future calculations by the EFD's and NAVFAC.

II. MAJOR ASPECTS OF THE MILITARY CONSTRUCTION PROCESS

There are several major aspects and perspectives of the MILCON process that require special attention. These include the roles of the Congress, the Naval Facilities Engineering Command (NAVFAC), the Engineering Field Divisions (EFD's), and the Facilities Acquisition and Construction Support Office (FACSO).

A. THE CONGRESS

In the Congress, the Military Construction (MILCON) Project funding process goes through four phases as depicted in Figure 2.1. These phases are presented in detail in Tables I through IV.

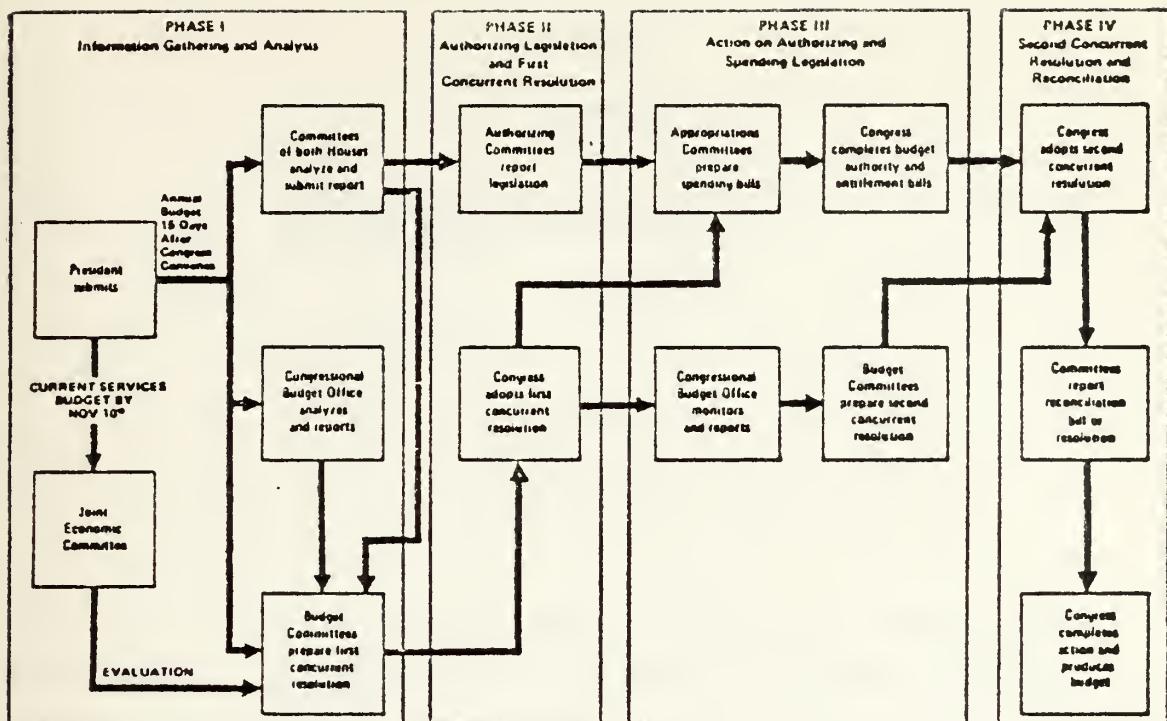


Figure 2.1 General Chronology of Congressional Budget Action

TABLE I

Phase I

10 November	President submits current services budget
31 December	Joint Economic Committee submits economic evaluation to budget committees
15th day after Congress convenes	President submits his budget
15 March	Committees and Joint Committees submit reports to budget committees
1 April	Congressional Budget Office submits report to budget committees
10 April	President submits budget amendments
15 April	Budget Committees report first concurrent resolution to their houses

TABLE II

Phase II

15 May	Committees report legislation authorizing new budget authority
--------	--

TABLE III

Phase III

15 July	President submits additional budget amendments
No Deadline	Appropriations committees prepare spending bills
No Deadline	Budget committees prepare second concurrent resolution
7th day after Labor Day	Congress completes action on budget authority and entitlement bills

TABLE IV

Phase IV

15 September	Congress adopts second concurrent resolution
No Deadline	Committees report reconciliation bill or resolution
25 September	Congress completes action, brings congressional budget timetable to a close

Table I depicts the information gathering and analysis phase in detail. Table II describes the time period during which the authorizing legislation and the

TABLE V

Subcommittees of the Armed Services Committees, 95th Congress

House	Senate
Intelligence and Military Applications of Nuclear Energy	Intelligence
Research and Development	Military Construction and Stockpiles
Seapower and Strategic and Critical Materials	General Procurement
Investigations	Arms Control
Military Installations and Facilities	Tactical Aircraft
Military Personnel	Research and Development
Military Compensation	General Legislation
	Manpower and Personnel

first concurrent resolution are passed. Table III is the time table for the Congressional actions on the authorizing and spending legislation. Table IV shows the final phase of the Congressional appropriations legislation action during which the second concurrent resolution and reconciliation are passed into law.

As shown in Table V, the MILCON Appropriations are handled in the House of Representatives by the Military Installations and Facilities subcommittee and by the Military Construction and Stockpiles subcommittee in the Senate.

These subcommittees review each submitted MILCON project separately. Due to the excellent reputation of these subcommittees with the rest of the Congress, their recommendations are seldom questioned. During Phase II each service head is called on to defend his program submission in detail. It is at this time that the need for accurate

cost estimates is imperative. If the subcommittee is confident that every effort has been made to develop an accurate estimate they are much more inclined to fund the associated project. [Ref. 1: p. A-19]

B. NAVAL FACILITIES ENGINEERING COMMAND

Naval Facilities Engineering Command is a sub-major claimant of the Naval Material Command whose responsibilities include the construction, maintenance, and repair of all Naval shore facilities. These facilities include all Navy-owned real estate and natural resources as well as all Naval shore installations.

C. ENGINEERING FIELD DIVISIONS

The first echelon below headquarters in the NAVFAC chain of command is the Engineering Field Division (EFD) level. There are six EFD's located in various locations to provide contractual jurisdiction over specific geographic regions as shown in Figure 2.2.

In the construction phase of operations, NAVFAC is responsible for the completion of each construction contract in accordance with all plans and specifications. These contracts are administered by Resident Officers in Charge of Construction (ROICC's). A ROICC reports directly to the EFD in all contract matters. He is also normally assigned to the installation as the Public Works Officer and, as such, reports directly to the installation Commanding Officer. [Ref. 2]

NAVFAC and the EFD's are responsible for furnishing the technical expertise in the determination of the need for new construction through the Shore Facilities Planning and Programming System (SFPS), for ensuring activity compliance

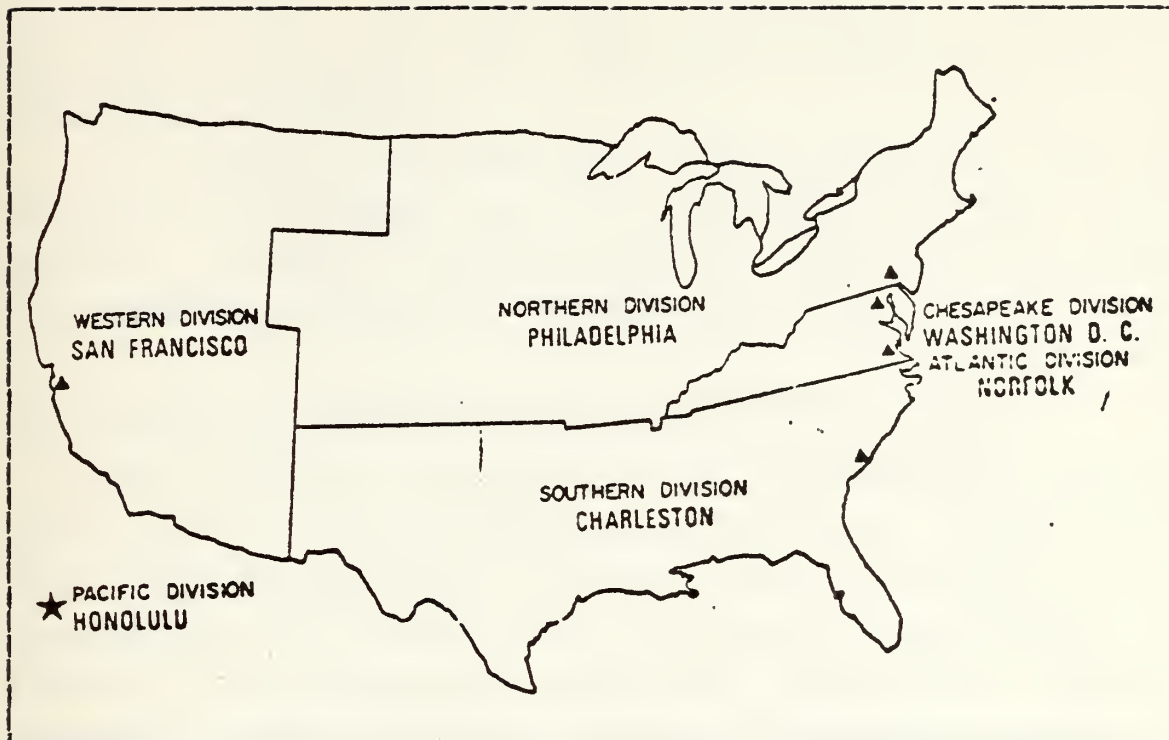


Figure 2.2 United States Showing Locations of Engineering Field Divisions

with instructions and criteria, and adequacy of cost estimates, as well as forwarding technical review comments to the appropriate level of the operational chain of command where decisions are made on funding and programming priorities. [Ref. 3:p. 245]

NAVFAC and the EFD's are also responsible for publishing planning guidelines and instructions to implement the SFPS, and providing engineering assistance where needed [Ref. 4].

D. MAJOR CLAIMANT

The activity major claimant is responsible for defining the activity's mission and projected base manning levels. Subsequent to development of SFPS documents, the major

claimant reviews and validates the documents. The major claimant coordinates its subordinate commands' military construction programs.

The activity is responsible for initiating planning actions and documents and for obtaining assistance where needed. Projects for correction of facility deficiencies are normally initiated at the activity level.

E. FACILITIES ACQUISITION AND CONSTRUCTION OFFICE

The Facilities Acquisition and Construction Support Office (FACSO) is the accountant for NAVFAC. FACSO uses a fully automated system to maintain accurate accounts of all construction and acquisition contracts administered by NAVFAC. In addition to making all construction contract payments, FACSO also issues periodic management reports in support of the EFD's.

F. COST ESTIMATES

At present, cost estimates are prepared by various methods. Among them are the use of engineering performance standards, the use of the Shore Facilities Planning and Programming Manual, as well as the use of established estimating practices and the general experience of the estimator. Even with these established and accepted estimating practices, there is still a need to add an additional factor to adjust the estimate to take into account the variability of the EFD's estimating practices.

Estimates for construction projects must include the approximate cost of every item that enters into the work. Unit costs are based upon the cost of material in finished condition. These include material and labor costs as well as the contractor's indirect charges, and overhead costs.

Material requirements are developed from quantity surveys, and material prices are obtained from past records that are adjusted to the current date or from suppliers' and manufacturers' quotations and catalogs. Estimated labor costs are obtained from historical data as recorded by the Facilities Acquisition and Construction Support Office (FACSO), from recognized estimating publications, and are adjusted for current labor rates in the local area. The local minimum government construction contract labor rates are set by the Department of Labor in accordance with the Davis-Bacon Act. It is usually necessary for this adjustment also to reflect other local conditions and proposed methods of construction. The material and labor charges should also reflect any unusual risks that might be encountered because of working conditions or scarcity of material and/or labor. Furthermore, if these unusual risks warrant their inclusion as a special item in the estimate, they should be priced on a material and labor basis, if possible; otherwise, a lump sum charge is standard practice.

The estimated indirect charges of the contractor include all items normally recognized by generally accepted accounting practices as overhead. This total charge varies with the type and extent of the construction and the location of the project. The contractor's estimated profit is set at a maximum of six percent of the estimated construction costs including indirect and overhead costs [Ref. 5:p. 2-3]. The factors which are used to calculate the estimated contractor's profit vary from the amount of competition and the size of the project to the contractor's need for work to stay in business. [Ref. 5: p. 2-2]

G. TIME ELEMENTS

The normal MILCON project is of sufficient complexity and magnitude that the time required for the designer to prepare the thirty five percent design documentation often exceeds a year. This documentation comprises thirty five percent of the total design effort and includes preliminary cost estimates, outline specifications, preliminary drawings, and supporting data. The thirty five percent design documents are necessary in order to determine an approximate estimate of the cost and scope of the project. This project complexity and magnitude makes the use of civilian commercial expertise almost mandatory as most activity and EFD engineering departments are not equipped to produce highly specialized design. Most project documentation is provided by Architect/Engineering (A&E) service contracts. These contracts are awarded in accordance with NAVFAC P-68 which details the procedures by which they are to be solicited, negotiated, awarded, and administered and the mandatory time envelopes associated with each phase. The requirements associated with each phase of design contracts vary with the type and size of contract. [Ref. 2]

Following the initiation of the project at the activity level the A&E contract documentation must be prepared by either the activity, if it has the capability, or by the cognizant EFD. The time period for this evolution is two to four months. Subsequent to the completion of the design contract which had encompassed a total of four to six months and produced the thirty five percent design and project engineering documents (PED), the activity or EFD puts the information into the proper format for submission to its major claimant and simultaneously to NAVFAC. By this time almost a year has elapsed since the initiation of the project. After the project is inserted into the CNC's

budget submission and into the President's budget request, it takes almost another year for the Congress to complete its action and provide funding, as shown in Figure 2.1.

H. INFLATION

Over the past eight years, when inflation was approaching twenty percent at one point, these time delays of twelve to eighteen months could mean that a project's original estimated cost could have risen substantially faster than the standard ten percent inflation rate called for in the SFPS documentation. A comparison of these two inflation rates would appear to show that the SFPS inflation factor may be too low.

In fact, however, the use of the constant ten percent inflation factor does have a tendency to fully offset the effect of inflation (in the long run). While the total actual costs rise, the cost estimates have risen at ten percent which closely approximates the actual average inflation rate over the past five years. Therefore, there appears to be no need for an additional inflation factor to account for the long run effects of inflation.

Inflation has had a detrimental impact on the reliability of those estimates made two to three years prior to submission and an especially detrimental impact if the estimate was not updated immediately prior to submission to the CNO. Project managers and major claimants are aware of this effect and are requiring that all estimates be updated for inflation and any other foreseeable changes immediately prior to submission to the CNO in an effort to ensure more accurate estimates.

III. ANALYSIS OF DATA

A. INTRODUCTION

The data on the 1065 projects over the last eight years were analyzed in an attempt to provide a better method for predicting the actual costs of a construction project using the original estimated costs as a predictor. The data were disaggregated by EFD as well as by fiscal year within each EFD. Linear regression analysis was used to obtain prediction equations. Equations for one EFD are examined in detail in this chapter with the detailed results from the other EFD's being presented in Appendix A.

B. DATA AND SOURCES

The data were obtained from PACSO Report number (MJBIDYL.CNTL (Act COST)) which lists each closed-out or completed construction project along with its authorized/estimated cost, and its actual cost, as well as its identification number, title of the project, and the activity at which it was constructed. The data obtained from PACSO were verified by comparison with the annual Composite 'As Enacted' Budgets provided by Congress to each EFD. These budgets list all MILCON projects separately for that fiscal year with a full explanation of the project and amount of funding authorized for it. The authorized amount in each case was found to be the same as the estimated cost and, therefore, the terms are used synonymously.

C. METHODOLOGY

The two actual and estimated costs for the projects were related through the use of linear regression analysis. Linear regression analysis can be simplistically defined as the fitting of a line to a plot of more than two related points by a method known as the least sum of squares. This method reduces the sum of the squared distances from each point to the line to a minimum and thereby provides a single linear equation which represents all of the plotted relationships [Ref. 6: p. 320].

The pairs of points are plotted using the actual cost as the dependent variable on the y coordinate and the authorized/estimated cost as the independent variable on the x coordinate. The resulting equation has the form:

$$Y=B_0 + B_1 \times X_i$$

where y is the expected actual cost of the proposed project, X_i is the authorized/estimated cost, B_0 is the y intercept, and B_1 is the slope of fitted line.

The accuracy of the fitted equations is denoted by the R^2 term. R^2 (Coefficient of Determination) is defined as the proportion of the total variation of Y as explained by the fitted equation. The fitted equation will reduce the variation of the actual cost from the estimated cost by the amount of R^2 [Ref. 6:p. 423]. R^2 is a measure of the amount of variability of the dependent variable that is explained by the fitted equation and is expressed in the form of a number between zero and 100. A higher percentage indicates a better fit and a more useful equation.

The standard error of the coefficient is a measure of the accuracy of the fitted coefficients of an equation. The standard error of the coefficient measures the deviation of the coefficient from the expected coefficient. The smaller

the standard error the more exact is the fit of that coefficient of the equation.

One would not expect any fitted line to predict the cost of any new project with 100 percent accuracy. Therein lies the need for an interval around the expected value in which the actual cost will lie with some degree of certainty. The following prediction equation is used to derive such an interval:

$$y \pm t(1-\alpha/2, n-2) (s) \sqrt{\frac{1}{n} + \frac{(X_0 - \bar{X})^2}{\sum X_i^2 - (n\bar{X}^2)} + 1}$$

[Ref. 7:p. 72]

The following terms apply to the preceeding equation;

\bar{X} is the mean authorized project cost for that EFD;

n is the total number of projects used in the regression (see Appendix A);

t is described as a student's t distribution with $n-1$ degrees of freedom. The level of certainty is selected at this point as it is needed to determine the appropriate t value (See Appendix C for Specific t values);

s is described in general as the standard deviation of the residuals (or the normal or expected distance the plotted observations lie from the fitted line);

Y is the figure used to denote the new or expected value of the actual cost;

α (alpha) is the significance level (.05);

X_0 is the estimated cost of the new project provided by the EFD;

$\sum x_i^2$ is the sum of the individual authorized costs squared.

The interval obtained from the above equation is the range in which the actual cost (Y) will fall with a given certainty or probability. The certainty or probability is entered into the equation via the t value provided by Appendix C. The specification of a specific probability is left to the user. The interval width can be controlled by an applicable rule of thumb that states that the smaller the probability used, the narrower the interval will be and vice versa.

D. RESULTS

Figure 3.1 is a plot of Chesapeake Division's fitted line and the prediction interval associated with an α of .05. This figure is representative of the other EFD's as well as Bethesda and Trident West.

1. Fitted Line

. The fitted line for Chesapeake Division with 77 observations over six years is

$$y = 1.6592 + .9307 \times \text{Authorized}$$

with standard deviations for $B_0 = 23.05$ and for $B_1 = .0126$.

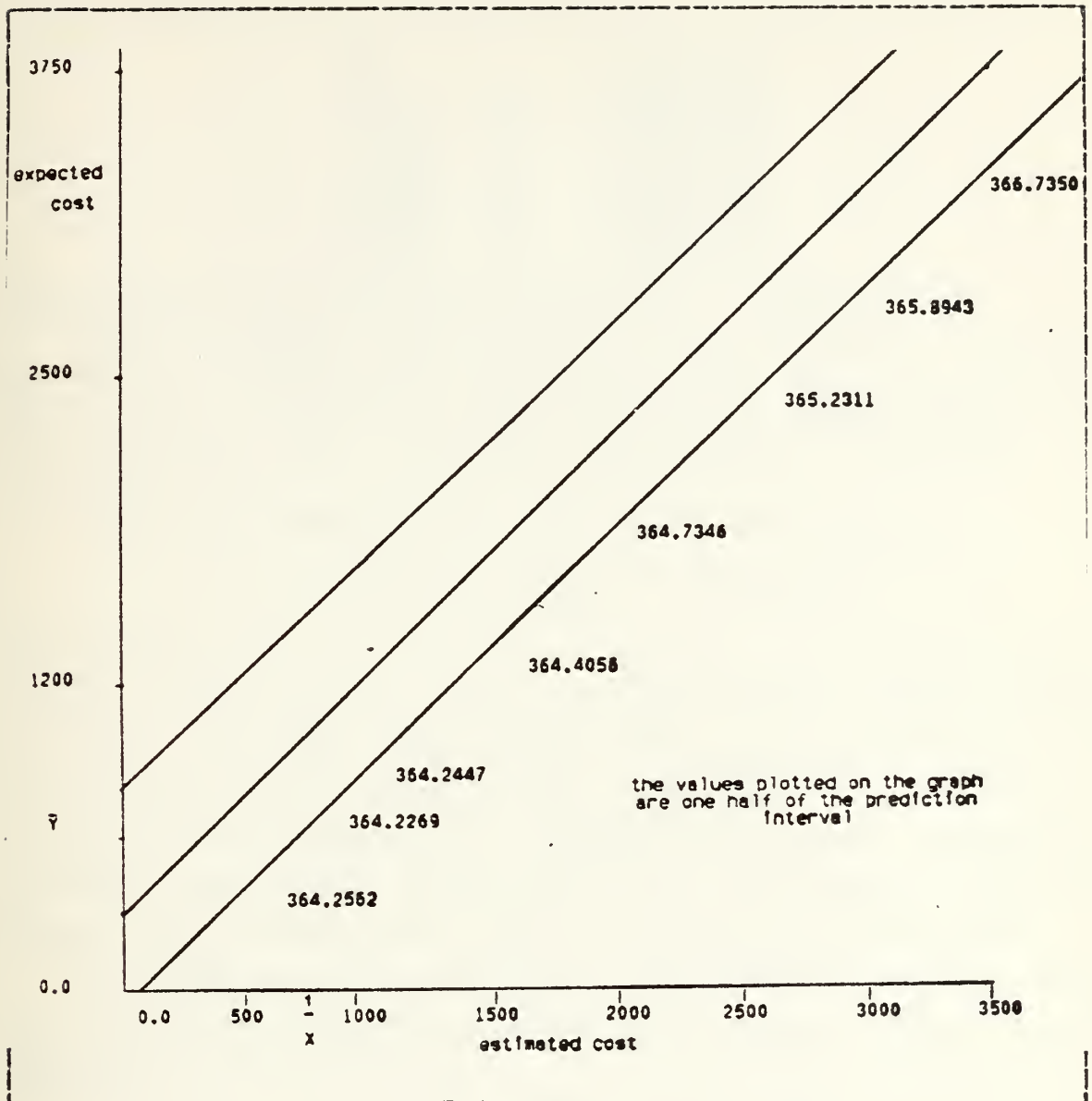


Figure 3.1 Detailed Plot of Chesapeake Division Fitted Line and Prediction Interval

2. Prediction Equation

The prediction equation for Chesapeake Division is

$$Y \pm (1.98)(182.77) \sqrt{\frac{1}{77} + \frac{(X_0 - 771)^2}{(580221900 - 777)(777)^2}} + 1$$

which results in the following ranges at selected points:

Xo		Interval
500	+/-	364.2516
771	+/-	364.2269
1000	+/-	364.2446
1500	+/-	364.4056
2000	+/-	364.7322
2500	+/-	365.2310
3000	+/-	365.8943
3500	+/-	366.7235

These ranges are graphically depicted in Figure 3.1.

The regression equations have been calculated for each EFD as well as Bethesda and Trident West and are presented in a summary form in Table VI and as an aggregate in Appendix A.

The fitted equation for the entire data set is

$$Y = 166.45 + .08412 \times \text{Authorized}$$

and produced an R^2 of only 26.42 percent. The low R^2 is due to the difference in the mean sizes of the normal MILCON projects and those mean sizes found in the Bethesda and Trident West construction project packages. When these two construction packages are introduced into the regression analysis their means distort the total data base to such an extent that a meaningful fitted line cannot be obtained.

The removal of the Bethesda and Trident West data from the regression analysis produces the following NAVFAC fitted equation

$$Y = 54.735 + .8657 \times \text{Authorized}$$

and

$$R^2 = 89.69 \text{ percent.}$$

This equation is useable by NAVFAC to predict the actual cost of a proposed project and, if used over the long run, will tend to reduce the estimating variance to near ten percent as the equation is capable of explaining only 89.69 percent of the variations of the present actual costs.

TABLE VI

Summary of Regression Equations

Naval Facilities Engineering Command

$$\text{Actual} = 54.735 + .8657 \times \text{Authorized}$$

Chesapeake Division

$$\text{Actual} = 1.6592 + .9307 \times \text{Authorized}$$

Atlantic Division

$$\text{Actual} = 31.049 + .7342 \times \text{Authorized}$$

Northern Division

$$\text{Actual} = 12.225 + .9492 \times \text{Authorized}$$

Southern Division

$$\text{Actual} = 2.02 + .3944 \times \text{Authorized}$$

Western Division

$$\text{Actual} = 41.657 + .9575 \times \text{Authorized}$$

Pacific Division

$$\text{Actual} = -1.093 + .3887 \times \text{Authorized}$$

Figure 3.2 is the plot of all the EFD's and Bethesda and Trident West's fitted lines which graphically illustrate the above comments along with the effect of the inclusion and removal of the Bethesda and Trident West data.

A review of the R^2 's for each EFD, provided in Appendix A, reveals that the Atlantic Division's overall R^2 is only 76.65 percent which is ten to fifteen percent lower

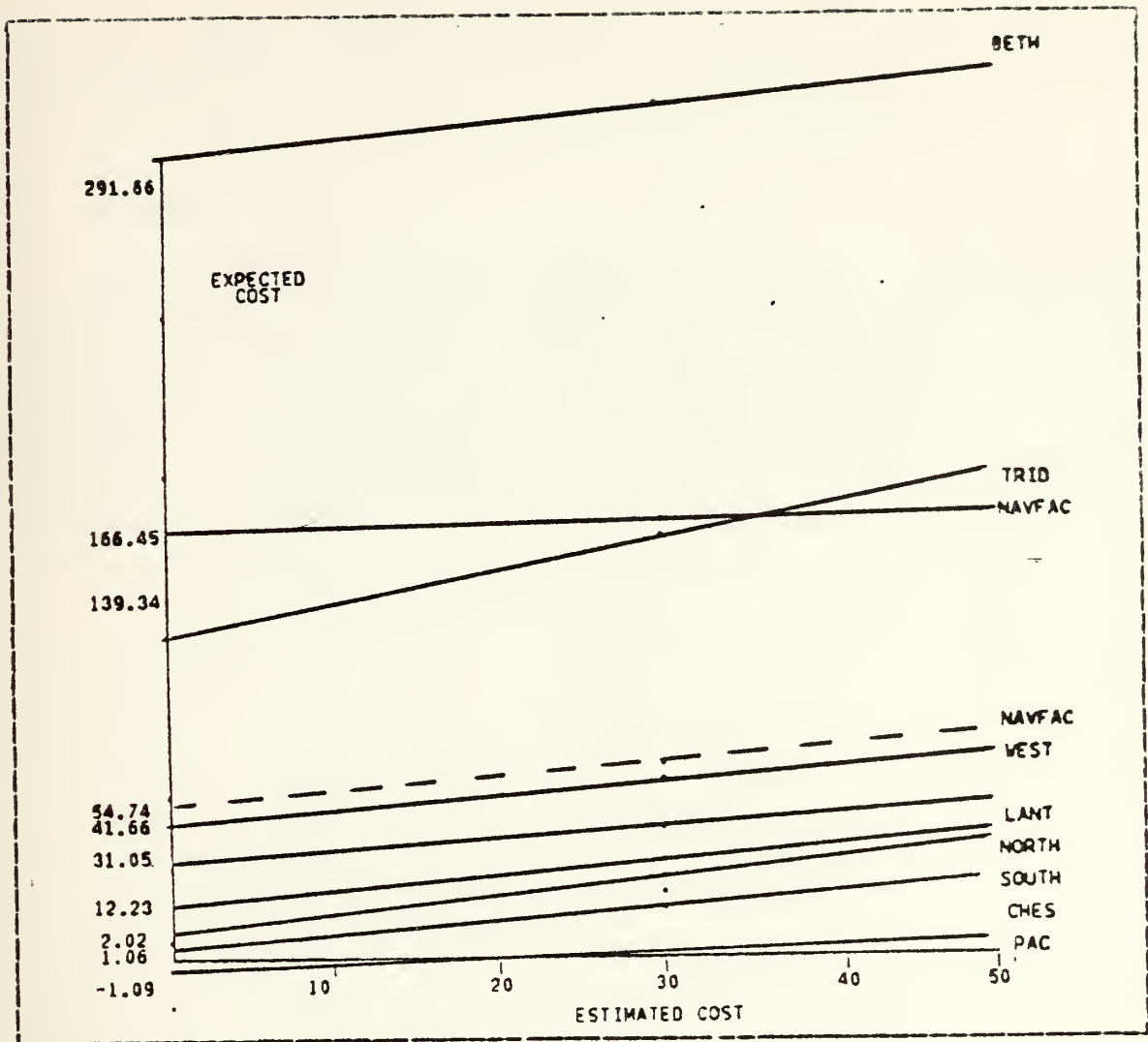


Figure 3.2 Plot of All Fitted Equations Including Bethesda and Trident West

than the other EPD's. Closer examination of the fiscal years' R^2 's indicate that in FY1979 an R^2 of only 69.9 percent was realized. This aberration is due to the occurrence of several large variances within the seventeen projects of that year. The causes of these variances are not known but due to their clustering in a single year would indicate an estimating problem or some other unusual problem

in that year. The removal of the FY 1979 data from the regression raised the overall Atlantic Division R^2 to 78.32 percent.

E. SUMMARY

Through the use of regresssion analysis, fitted equations for each EFD and NAVFAC as a whole were derived. Using these equations and the given prediction interval equation, an estimate of a prediction interval on actual cost of a proposed project can be derived with any desired degree of confidence.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

The conclusion drawn from the derived equations is summed up in the NAVFAC equation. The NAVFAC equation can be interpreted to mean that the data are linearly related to such an extent that 89.69 percent of the variability of the actual costs in the past eight years' NAVFAC MILCON projects can be explained by their estimated/authorized costs. This statement does not include the two special cases of Bethesda and Trident West.

With the overall Atlantic Division R^2 being 76.65 percent, which is ten to fifteen percent lower than any other EFD, there appears to be the possibility of a special estimating problem that is peculiar to Atlantic Division. The presence of the wide variations between the actual costs and the estimated costs would indicate that there may be a problem. However, there is also the possibility that the estimates were the best possible but the contracts themselves may have had peculiar problems and, hence, created cost problems. Due to the special problems that Atlantic Division appears to have, as indicated by the low R^2 values shown in Appendix A, it can be concluded further study is necessary.

B. RECOMMENDATIONS

At the close of each year, those projects that have been closed out by each EFD during that year should be added to the bottom of that EFD's data base and a like number removed from the top. This procedure will provide a data base of a

constant size that will not become too large to handle or too small to provide an accurate regression. Following insertion of the new projects, the regression analysis should be repeated and the results reviewed in the same manner as previously discussed. The effect of the application of the fitted equations will not be evident until projects that have been estimated using these factors are closed-out and their actual costs compared with their estimated costs.

It is noted that all of the slopes (B_1 's) in the regressed equations are less than 1.0 which is indicative of a consistent shrinkage of the estimated to the actual cost of the project. This reduction appears to be due to a systematic overestimation of all projects. This overestimation may be attributable to an attempt to offset the effects of inflation or to ensure that the size of the contingency fund is sufficient to cover all circumstances. A review of the past five years' inflation would indicate that the average annual inflation rate is approximately ten percent. With NAVFAC P-448 [Ref. 5] calling for a ten percent inflation factor to be used consistently in estimating, inflation should not be a factor in the variance from the authorized/estimated cost. However, the slopes would indicate the ten percent factor is unnecessarily high. Consequently, there is a possibility that the inflation factor in P-448 should be adjusted. This possibility and the size of the adjustment will require further study.

A second possible explanation for the shrinkage is the size of the contingency or management reserve factor used in the current estimating process. At present, NAVFAC P-448 allows for ten percent of the construction costs to be added as a contingency factor. It would appear that the construction cost estimates are of sufficient accuracy so as

to largely allieviate the need for a portion of the contingency funding. This possibility and the size of the possible adjustment also will require further study.

Upon completion of the data manipulation and linear regression process, it was noted that Atlantic Division appears to have had some special problems but, overall, the EFD's and their ROICC's have consistently brought their MILCON projects to completion below the estimated cost. This speaks highly of their estimating, managerial, and administrative skills. The indication of consistent overestimation is the basis for the recommended studies into the possibility of the reduction of the inflation and contingency factors presently used in MILCON cost estimating. More accurate estimates would conceivably improve the NAVFAC credibility with the Congress which, among other benefits, could generate more favorable considerations for the MILCON program in general.

APPENDIX A

EFD EQUATIONS

This appendix is designed to provide an aggregate of the data derived from the regressions of the individual EFD data.

Listed are:

1. The names of the EFD's on which the data were obtained
2. The fitted equation for each EFD and each fiscal year in each EFD
3. The sum of the authorized/estimated costs squared
4. The standard deviation of the residuals from the fitted line
5. The number of projects used in the regression analysis
6. The resulting R²

EFD	FITTED	SUMM	STD DEV		R ²
	EQUATION	SQUARES	OF RESID	#OBS	
		$\sum x^2$	(s)		(n)
=====					
NAVFAC	54.735+.8657*AUTH		478.64	999	.8969
		15178549000			

CHESEPEAKE DIVISION		580221900			
OVERALL	1.6592+.9307*AUTH		182.77	77	.9864
74	13.160+.9902*AUTH		245.31	18	.9700
75	-20 +.9101*AUTH		71.12	12	.9923
76	69.8+.6640*AUTH		70.05	13	.9784
77	-11.5+.9150*AUTH		47.87	15	.9998
78	6.87+.8770*AUTH		60.60	12	.7403

79	-120+1.205*AUTH	59.85	18	.9981
----	-----------------	-------	----	-------

SOUTHERN DIVISION	3133099000
-------------------	------------

OVERALL	2.02+.8944 *AUTH	406.14	214	.9140
74	73.77+.8928*AUTH	337.9	72	.9487
75	-4.41+.9472*AUTH	513.9	67	.9255
76	96.22+.5924*AUTH	371.02	40	.7464
77	17.48+.7468*AUTH	209.42	30	.9107
78	29.22+.7571*AUTH	160.05	21	.7596
79	29.29+.9107*AUTH	58.33	11	.8596

ATLANTIC DIVISION	1737286000
-------------------	------------

OVERALL	31.049+ .7342*AUTH	414.68	183	.7665
74	-12.122+ .9876*AUTH	285.24	53	.9737
75	-91.99 + .9055*AUTH	332.15	38	.9090
76	36.59 + .7029*AUTH	193.80	39	.9866
77	69.792+ .6376*AUTH	200.44	22	.9956
78	53.273+ .6244*AUTH	121.56	24	.9639
79	393.18 + .0220*AUTH	689.70	17	.6990
80	CANNOT REGRESS ON ONLY 2 OBSERVATIONS			

NORTHERN DIVISION	1991578000
-------------------	------------

OVERALL	12.225+ .9492*AUTH	264.42	125	.9464
74	58.441+ .9874*AUTH	251.53	29	.9750
75	19.653+ .8182*AUTH	266.53	21	.9215
76	51.404+ .9503*AUTH	350.61	34	.9296
77	9.075+ .8739*AUTH	121.44	20	.9235
78	11.028+ .8214*AUTH	49.33	11	.7982
79	-75.282+1.0948*AUTH	52.59	6	.9931
80	35.416+ .8310*AUTH	38.21	4	.9395

PACIFIC DIVISION	2347655000
------------------	------------

OVERALL	-1.093+ .8887*AUTH	331.16	128	.9281
74	51.869+ .8851*AUTH	219.33	42	.9680

75	-32.611+1.0145*	AUTH	136.52	25	.9896
76	50.090+ .7848*	AUTH	549.98	14	.8862
77	-124.030+ .9394*	AUTH	499.01	22	.8792
78	2.232+ .7596*	AUTH	190.79	16	.9478
79	-70.86+1.0196*	AUTH	111.66	7	.9730

WESTERN DIVISION

5388709000

OVERALL	41.657+ .9575*	AUTH	596.5	303	.8593
74	26.770+1.1800*	AUTH	570.33	70	.8085
75	83.055+ .9045*	AUTH	421.43	69	.9477
76	59.004+ .7797*	AUTH	147.73	68	.9683
77	46.428+ .7685*	AUTH	291.95	49	.9528
78	-8.6824+ .9699*	AUTH	109.67	33	.9660
79	-36.780+1.0619*	AUTH	68.53	14	.9565

TRIDENT WEST

4365602000

OVERALL	139.34+ .8527*	AUTH	574.51	44	.9809
74/75	242.68+ .8398*	AUTH	941.30	12	.9842
76	36.936+ .8454*	AUTH	238.33	14	.9652
77	-163.65+1.0594*	AUTH	218.72	10	.9758
78	-128.18+1.1912*	AUTH	349.54	8	.9708

BETHESDA HOSPITAL

323362239

OVERALL	291.66+ .868*	AUTH	595.20	7	.9880
---------	---------------	------	--------	---	-------

APPENDIX B

MEANS AND AVERAGES

The 'mean authorized' figure is the average of the authorized amounts for all projects in that EFD.

The 'mean actual' figure is the mathematical average of the actual costs for all projects in that EFD.

The 'average percent shrinkage or growth' in the EFD is the mathematical average of the percentages of shrinkage or growth found in each project in the individual EFD. A project is said to shrink if the actual cost is less than the authorized amount and is said to grow if the actual cost is more than the authorized amount.

The 'average weighted variance' is a comparison of the total authorized amount for all fiscal years and total actual cost expressed as a percentage of the total authorized amount for that EFD.

=====

ATLANTIC DIVISION

MEAN AUTHORIZED	1075.	MEAN ACTUAL	877.5
AVERAGE	15.096	PERCENT SHRINKAGE IN THIS EFD	
AVG WEIGHTED VARIANCE	22.529	PERCENT SHRINK	

=====

CHESAPEAKE DIVISION

MEAN AUTHORIZED	771.	MEAN ACTUAL	718.5
AVERAGE	9.674	PERCENT SHRINKAGE IN THIS EFD	
AVG WEIGHTED VARIANCE	7.268	PERCENT SHRINK	

=====

NORTHERN DIVISION

MEAN AUTHORIZED	821.	MEAN ACTUAL	791.4
AVERAGE	3.567	PERCENT SHRINKAGE IN THIS EFD	
AVG WEIGHTED VARIANCE	3.732	PERCENT SHRINK	

=====

PACIFIC DIVISION

MEAN AUTHORIZED 1010. MEAN ACTUAL 893.6

AVERAGE 10.027 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 13.064 PERCENT SHRINK

=====

SOUTHERN DIVISION

MEAN AUTHORIZED 1037. MEAN ACTUAL 929.2

AVERAGE 7.846 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 11.570 PERCENT SHRINK

=====

WESTERN DIVISION

MEAN AUTHORIZED 1008. MEAN ACTUAL 1006.2

AVERAGE 2.172 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 0.136 PERCENT SHRINK

=====

TRIDENT WEST

MEAN AUTHORIZED 2348. MEAN ACTUAL 2138.5

AVERAGE 4.192 PERCENT GROWTH IN THIS EFD

AVG WEIGHTED VARIANCE 9.803 PERCENT GROWTH

=====

BETHESDA

MEAN AUTHORIZED 3766. MEAN ACTUAL 3524.0

AVERAGE 0.079 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 6.876 PERCENT SHRINK

=====

APPENDIX C

SELECTED STUDENT'S T DISTRIBUTION VALUES

The values listed are those specific Student's t distribution values applicable to the ninety, ninety-five, and ninety-nine percent prediction intervals. The n values listed are of such size so as to encompass the numbers of projects found in the EFD's and NAVFAC as a whole.

1-a/2	.95	.975	.995
n			
60-	1.671	2.000	2.660
120	1.658	1.980	2.617
inf	1.645	1.960	2.576

LIST OF REFERENCES

1. Navy Postgraduate School, Practical Comptrollership Course, Department of the Navy, Monterey, CA, 1980
2. NAVFAC P-68, Contract Administration, Department of the Navy Naval Facilities Engineering Command, Washington, D.C., 1981
3. Haydon, D.M. and Schroder, K.N., Navy Public Works Administration, M.S. Thesis, Naval Postgraduate School, Monterey, 1981
4. OPNAV Instruction 11010.1 Series, Shore Installation and Facilities Planning and Programming Manual, Department of the Navy, Washington, D.C.
5. NAVFAC P-448, Conceptual Military Construction Cost Engineering Cost Data, Department of the Navy Naval Facilities Engineering Command, Alexandria, VA, 1976
6. Wonnacott, T.H. and Wonnacott, R.J., Introductory Statistics John Wiley & Sons, New York, 1972
7. Neter, J. and Wasserman, W., Applied Linear Statistical Models Richard D. Irwin and Co., Homewood, IL, 1974

INITIAL DISTRIBUTION LIST

	No. Copies
1. Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2. Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee, Virginia 23801	1
3. Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
4. Department Chairman, Code 54 Department of Administrative Science Naval Postgraduate School Monterey, California 93940	1
5. Dan C. Boger, Code 54Bk Department of Administrative Science Naval Postgraduate School Monterey, California 93940	1
6. LCDR William Talutis, USN Code 54Tu Department of Administrative Science Naval Postgraduate School Monterey, California 93940	1
7. Shore Activities Planning and Programming Division OP-44 Office of Chief of Naval Operations Navy Department Washington, DC 20350	1
8. Commander Naval Facilities Engineering Command 200 Stovall Street Alexandria, Virginia 22332	1
9. Commanding Officer Chesapeake Division Naval Facilities Engineering Command Washington Navy Yard Washington, DC 20374	1
10. Commanding Officer Northern Division Naval Facilities Engineering Command Philadelphia, PA 19112	1
11. Commander Atlantic Division Naval Facilities Engineering Command Norfolk, VA 23511	1
12. Commanding Officer Southern Division Naval Facilities Engineering Command Charleston, SC 29411	1

- | | | |
|-----|---|---|
| 13. | Commanding Officer
Western Division
Naval Facilities Engineering Command
San Bruno, CA 94066 | 1 |
| 14. | Commander
Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, HI 96860 | 1 |
| 15. | LT William J. Paine, USN
NMCB-4
FPO San Francisco 96601 | 1 |

Thesis

198035

P1194 Paine

c.1

A statistical
evaluation of military
construction project
cost estimates. ry

28 JUL 64

33005

Thesis

198035

P1194 Paine

c.1

A statistical
evaluation of military
construction project
cost estimates.

thesP1194

A statistical evaluation of military con



3 2768 001 97119 5

DUDLEY KNOX LIBRARY